No. III.] [SECOND SERIES.

PRICE'S RETORT FURNACE

FOR

REHEATING AND PUDDLING.

PRINTED FOR PRIVATE CIRCULATION.

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Price's Retort Furnace.

Nearly two years since I called the attention of my clients to this furnace, which I had seen at Woolwich Arsenal in 1874, and which was made the subject of a strongly commendatory paper before the Iron and Steel Institute by Mr. I. Lowthian Bell in 1875.

The system is this: The waste gases are employed, 1st, to preheat the solid fuel which is to be burned on the grate; 2d, to distil the gases from it regularly, so as to perfect their combustion; and, 3d, to preheat the air for combustion. Either bituminous or anthracite coal may be used.

During the last winter, my assistant Mr. Laureau and myself, repeatedly examined the working and repairs of the furnace at Woolwich Arsenal. We found—

1st. That seven heating and puddling furnaces had been constructed there, that ten ordinary furnaces were about to be altered to the Price system, and that the invention was making progress elsewhere.

2d. That an important change had been made in the construction—carrying the waste gases to the retort in an overhead flue, as shown in the accompanying engraving, rather than underneath the furnace, and so adapting the system to *existing furnaces* by simply substituting the new fire-box and retort for the old fire-box.

The advantages claimed for the furnace, and the reasons for them, may be briefly summed up as follows:

1st. Its cheapness and convenient adaptation to existing works.

2d. Its economy as a reheating furnace in waste or oxidation. This saving averages a little above 2 per cent. of iron

heated (piles of large bars), at Woolwich. There is also a greater yield of iron in puddling.

3d. Its economy in fuel. This, in both puddling and heating, averages over 40 per cent., as compared with the ordinary furnace. It, however, furnishes no heat to boilers.

The reasons are: approximately perfect combustion, chiefly by means of the interception of any free air that may come through the grate, by a constant stream of gas; and a regular temperature due to charging red-hot fuel upon the grate.

Before proceeding with a description of the Price furnace and its results, I would remark that, as far as I am aware, the Siemens gas-furnace is the most highly developed and the very best type in use. But however indispensable the regenerative gas-furnace may be for steel-melting and for some other uses, it is always costly, and in old works it sometimes requires a great change, if not a complete transformation of plant. It also requires a depth of some ten feet below the working level, and this is often impracticable on account of water. Tanks, either of metal or of masonry, to protect regenerators from water, are unsatisfactory.

Description.—The Price furnace is partially a gas-furnace, and it embraces some of the features of the regenerative system, as the temperature of the air, as well as that of the gaseous and fixed constituents of the coal, is raised by the waste heat before it enters the chimney.

Fig. I. is a longitudinal section through centre of furnace.

Fig. II. is a horizontal section.

Fig. III. is a cross-section through heating-chamber.

Fig. IV. is a horizontal section through air-chamber and lower part of retort-chamber.

Fig. V. is a vertical section through retort and air-chamber.

A is a combustion-chamber or fire-box, furnished with grate-bars in the ordinary way; B a heating-chamber or hearth, separated from A by the usual bridge; C the neck leading into a flue, D, opening to the retort-chamber E. In the centre of this chamber is a circular fire-brick pillar, F, on which is placed a cast-iron cylindrical air-vessel, G, protected all around by fire-brick.

On this air-vessel G is built the retort H, the lower part of which is made of brick, while the upper part is of cast iron. At the top of the retort, and above the closed end of the chamber, is placed a hopper, I, in the throat of which are fitted two doors, J, worked by a lever from the ground. This feeding apparatus may be of any other suitable construction. In the fire-brick portion of the retort are two passages, L L, the one leading to the combustion-chamber, and the other to the outside of the furnace for the insertion of stoking tools to force the fuel forward into the combustion-chamber. The entrance to the outer passage is closed by a tight door.

Near the bottom of the chamber E, and in a line with the centre of the air-vessel G, are pipes, M M, inserted in the walls of the chamber and passing all around it, as shown in Fig. IV. On the inner side of these pipes, and opening into the chamber E, are a number of holes, N N N, leading into the space around the pipes M M, which space affords room for expansion and for a free circulation of heat. These pipes are connected with the blast from a fan or from any suitable blower, at Q. The air passes into the chamber G, and is delivered through the outlet R in the ash-pit S directly under the grate.

It will be seen from this description that the retort-furnace embraces some of the best features of the regenerative system, while it entirely dispenses with its complications of producers, regenerators, and reversing-valves.

To Start the Furnace.—The bottom of the retort is filled with wood upon which two or three hopperfuls of coal are dropped; a fire is kindled on the grate, and the retort is gradually filled up as the wood and coal ignite. By the time the fuel at the top descends to the bottom it becomes heated to redness—it is, in fact, coke, when bituminous coal is employed. A continuous supply of fuel is then kept up; it is all fed from the top, through the hopper, without access of air.

The Working of the Furnace.—The gases generated in the lower part of the retort and in the combustion-chamber pass over the bridge into the heating-chamber, up the neck C, through the flue D, thence into the retort-chamber, filling the spaces around, giving up their heat to the retort H, the air-

vessel G, and the air-pipes M M; the residue is then carried down and passes through the flue K to the stack; but the heat that was stored up in the gases is carried back into the furnace by the heated air and fuel.

A very important feature is that a continuous stream of gases, which must, of course, be regularly distilled in the retort, passes over the grate and takes up any unconsumed air that may get through the grate, thus preventing it from going over the bridge and oxidizing the metal.

It is important to keep the retort well filled, so that the fuel will heat gradually, which aids it in giving up its gaseous constituents without sticking to the retort. The grate is kept well covered with a bed of brightly-burning coke about 6 inches in thickness. Every ten or fifteen minutes, according to the requirements of the case, some hot coke from the retort is pushed upon the grate. This hot coke does not cool the furnace, but keeps up an even temperature, which is indispensable to heating with the highest economy; and the coke gives off no watery vapor to oxidize the metal.

At intervals a crooked rod is run from the back stoking-door up into the retort, so as to stir up the coal and check any tendency to clogging. This precaution seems to be quite sufficient. In case of emergency, however, a bar can be run through the hopper down into the retort; but this is never needed if the retort is kept full.

It is not necessary to light up every week, as, by filling up the retort and closing the ash-pit doors and the chimney-damper, the fire is kept alive from Saturday till Monday, so that it can be brought up to working heat in an hour and a half on Monday morning. The fire being once started, the operation goes on uninterruptedly for weeks and months, except when stopped for occasional repairs.

The blast has about the same pressure as in the ordinary furnace; it has slightly more friction to overcome in the pre-heating pipes. The quality of the flame can be regulated by means of the air-pipe damper, and a reducing or oxidizing flame obtained as circumstances demand. In short, there is no more difficulty in running a retort-furnace than an ordinary

one, and any furnace-man with fair intelligence can, in a few days, learn how to manage it.

Results in Puddling.—The retort-furnace and the ordinary furnace have been working side by side at Woolwich Arsenal for more than three years, under the same management and with the same coal and iron; any comparison between the two should therefore be a fair one.

The first results obtained, as given by Mr. I. Lowthian Bell in his paper read before the Iron and Steel Institute at the meeting in 1875, are as follows:

PRICE'S SINGLE PUDDLING-FURNACE—COLD AIR.

Pig-iron delivered to furnace			188 tons	$\frac{1680}{2240}$
Scrap-iron " "			31 "	$\frac{448}{2240}$
			219 "	$\frac{2128}{2240}$
Fettling used	49 tons	$\frac{1942}{2240}$		
Coal	149 "	$\frac{20}{2240}$		
Puddled bars received			184 tons	$\frac{183}{2240}$
Scrap-balls received			28 "	$\frac{883}{2240}$
			212 "	$\frac{1066}{2240}$

Consumption per ton of puddled iron and scrap-balls.

Pig-iron and scrap-iron	1 ton	$\frac{78}{2240}$
Fettling		526 lbs.
Coal		1570 "

This single furnace worked 12½ tons of pig per week.

PRICE'S DOUBLE PUDDLING-FURNACE—COLD AIR.

Pig-iron delivered			603 tons	——
Scrap-iron			82 "	$\frac{1232}{2240}$
			685 "	$\frac{1232}{2240}$
Fettling used	70 tons	$\frac{37}{2240}$ lbs.		
Coal	350 "	$\frac{92}{2240}$ "		
Puddled bars received			578 tons	$\frac{1634}{2240}$
Scrap-balls "			75 "	$\frac{43}{2240}$
			653 "	1677 lbs.

Consumption per ton of puddled iron and scrap-balls.

Pig and scrap iron	1 ton	$\frac{108}{2240}$
Fettling		240 lbs.
Coal		1,200 "

This double furnace puddled 25 tons of iron per week.

These trials were made in furnaces worked by the draught of the chimney alone, the air entering the fire-place at the temperature of the atmosphere. In the following experiment a fan was used, and the air was delivered under the grate heated to 300° F. The work done in a week was 26½ tons, instead of 25 when using cold air.

PRICE'S DOUBLE PUDDLING-FURNACE—HOT-BLAST.

Pig-iron delivered to furnace..................		26 tons $\frac{1120}{2240}$
Scrap-iron "		3 " $\frac{448}{2240}$
		29 " $\frac{1568}{2240}$
Fettling used................	5 tons $\frac{666}{2240}$	
Coal........................	13 " $\frac{584}{2240}$	
Puddled bars received....		24 " $\frac{2168}{2240}$
Scrap-balls received.........................		3 "

Consumption per ton of puddled iron and scrap-balls.

Pig and scrap iron.........................	1 ton 119 lbs.
Fettling....................................	425 "
Coal..	1057 "

The charges in this double furnace were about half a ton, but in later practice, by using Witham's mechanical rabble, the charges were increased to ¾ ton, and the amount of coal consumed was brought down as low as 812 lbs. per ton of puddled iron.

ORDINARY PUDDLING-FURNACE.

In all their past and current experience at Woolwich there has never been used less than 2,576 lbs. of coal per ton of iron in the ordinary single puddling-furnace, and never less than 2,016 lbs. in the double furnace.

The iron puddled is largely old cannon-balls and shells, and the coal contains from 8 to 10 per cent. of ash. As the two systems of furnaces are continually employed on the same kind of work, the following comparative table may be taken as a fair average result:

	Iron, charge cwt.	Coal, common furnace, cwt.	Coal, Price furnace, cwt.	Gain per cent.
Single furnace.....	5	23½	13½	42½
Double "	10	18	9½	47
" " (Witham's rabble)......	15	15	7½	50

The following tables are the results of experience in 1876:

NO. 14.—PRICE'S SINGLE PUDDLING-FURNACE.

No. of shifts worked, 378. Charges, ¼ ton.

Weight of iron charged	469 tons	1,008 lbs.
" " " yielded	458 "	939 "
" " scrap-balls	66 "	1,834 "
" " fettling	111 "	716 "
" " coal consumed	361 "	520 "
Loss on yield		2.35 per cent.
Consumption of coal per ton (including scrap-balls)	1,540 lbs.	
Fettling per ton	474 "	

NO. 3.—PRICE'S DOUBLE PUDDLING-FURNACE.

No. of shifts, 142. Charges, ¾ ton.

Weight of iron charged	511 tons	1288 lbs.
" " " yielded	507 "	1664 "
" " scrap-balls	46 "	2072 "
" " fettling	131 "	2094 "
" " coal consumed	217 "	784 "
Loss in yield		0.75 per cent.
Coal per ton (scrap-balls included)		877 lbs.
Fettling per ton		532 lbs.

After five heats a charge of one-half ton of scrap-iron is used, and from 6 to 10 per cent. of it is wasted with a cutting flame for the purpose of raising the bottom. The fettling used is a rich tap-cinder, and in some cases the yield of iron is higher than the charge.

All the figures given above are official, from the books of the Royal Gun Factories, and can therefore be relied on.

At Mr. Witham's works, Kirkstall Road, several retort-furnaces have for some time been in use for puddling, and their performance seems in every way to confirm the experience at Woolwich. At the fall meeting of the Iron and Steel Institute Mr. Witham, after having stated that the coal consumption at his works in the Price furnace was 932 lbs. to the ton of puddled bars, went on to say: "I do not know whether it will be out of place for me to state here that I have nothing but double furnaces at work, with charges of 15-cwt. heats, all worked by my machine (a mechanical rabble), and that my last year's average was 1,705 lbs. of coals used per ton of

puddled bars produced, including getting up of furnaces and broken turns for furnaces standing occasionally, so that the retort-furnace shows a saving of 773 lbs. to the ton of puddled bars produced, or, in my case, a saving of 46 per cent. of fuel." Mr. Witham also said that the waste was 3.3 per cent. and the fettling 735 lbs., this fettling consisting of ⅞ ore and ⅛ tap-cinder. Mr. Witham said, in private conversation in March, 1877, that his retort-furnaces had been running without any trouble since 1874, and that the economy in fuel had remained close on to 50 per cent., while repairs and maintenance were no higher than in the ordinary system.

Conclusions on Puddling.—In a late paper before the *London Association of Foremen Engineers*, Mr. James Ronald concludes a discussion of the Price furnace with the following facts: The puddling of 1 ton of iron is done with about 7 cwts. of fuel against about 18 cwts. in the ordinary furnace. In the Price furnace but 20½ cwts. of pig are requisite for a ton of puddled bars, while 21½ cwts. of pig are required in the ordinary furnace. There is also a saving in fettling, and a great saving in repairs, viz., 1s. per ton against 3s. in the common furnace.

Results in Heating and Welding Iron.—The retort-furnace seems to have even greater advantages for these purposes than for puddling, and the results obtained at Woolwich show it to be as economical as any known heating furnace. The iron made at the Royal Gun Factories is an exceedingly strong and dry iron, and the best practice in the ordinary furnace has been 896 lbs. of coal to the ton of iron reheated. This figure may seem high, but it must be remembered that the iron treated here is totally different from that used for rails, which is usually weak and cindery, having been puddled at a low heat; it is, therefore, reheated with a correspondingly small amount of coal. The use of the Price furnace has reduced the average amount of coal to 448 lbs., and in some cases as low as 420 lbs., per ton of finished iron, with from 5 to 6 per cent. waste by oxidation against 7 to 8 per cent. in the ordinary furnace. The piles welded weigh from half to three-

quarters of a ton. Here then, is a clear saving of half the fuel and of 2 per cent. waste.

The retort-furnace has never been used in heating steel ingots, but from its working in heating iron, an approximate idea of its qualities as a steel-heating furnace can be formed. Mr. William Price, Chief of the Forge Department at Woolwich, said, in the discussion on Mr. I. L. Bell's paper: "It was just at the point when iron was cindering that a steel ingot was at its climax of heat, but at this point half of the work was yet to be done in the iron and as much more fuel burned. In the gun factories they had carefully observed that in dealing with large masses, twelve tons of iron would take ten hours to heat. At the expiration of five hours, cindering would commence, but it would take five hours longer before its temperature was raised to a fit state for welding, while at least as much more fuel would be used in the second period as in the first. It was, therefore, misleading to compare the results of furnaces heating steel ingots and those heating iron, as he was thoroughly convinced only one-half the fuel was necessary, and that, where a ton of iron took 8 cwt. of coal to heat it, a ton of ingots should not take more than 4 cwt., and he should be very much surprised if they were not heated in the retort-furnace for 2 cwt. of coal per ton."

Gas Analyses.—Some analyses of the gases, as they pass the neck of the furnace, were made at the Royal Laboratory of the Ordnance Department.

The analysis of the heating-furnace escaping gases was found to be as follows:

Carbonic acid	15.9 vols, or	22.8 by weight.
Oxygen	2.2 "	2.3 "
Nitrogen	81.9 "	74.9 "
	100.00	100.00

Mr. Ronald, in the paper mentioned, says: "This exhibits an all but perfect result; the whole of the fuel is consumed in a condition so as to exert its utmost energy and greatest heating capacity, and give to the furnace the highest possible results that fuel can accomplish. Perhaps no

better evidence of perfect combustion has ever been taken during a process of manufacture."

The analysis of puddling-furnace gases during the operation was:

Carbonic oxide	13.07 vols.,	or 13.39	by weight.
" acid	7.76 "	12.49	"
Hydrogen	7.35 "	.53	"
Nitrogen	71.82 "	73.59	"
	100.00	100.00	

It will be seen that this analysis shows an excess of carbonic oxide, which fact is adverse to the theory of perfect combustion. But it is well known that in puddling this carburized flame is necessary, so as not to waste too much when the fine particles of iron are just coming to nature on the top of the bath; or, in the words of the puddlers, "The iron must be covered with flame."

MAINTENANCE.—The cost of repairs and maintenance seemed at first to be about the same as in the ordinary system. Mr. William Price stated in 1875 that at Woolwich an ordinary reheating furnace gave 900 tons of iron heated at the rate of 6d. per ton for repairs; a reheating retort-furnace gave 1,000 tons of iron heated at 6½d. per ton; an ordinary single puddling-furnace gave 470 tons of iron at a cost of 2s. 11d., and a single retort-furnace gave 503 tons at a cost of 3s.; a double retort-furnace gave 500 tons of iron at a cost of 1s. 6d. per ton for repairs. Mr. Ronald, in the paper previously quoted, says the repairs of the double retort furnace have been reduced to 1s. per ton.

It would appear also from still more recent experience that this class of expenses has been reduced. Taking, for instance, the results of No. 3 Price furnace (before mentioned), obtained from December 10, 1876, to March 16, 1877, we find the corresponding expenses of repairs to have been as follows:

Dec. 23.—Enlarging heating-chamber	$12 50
Feb. 10.—New bridge and sides to furnace, and repairing crown and jambs to dandy	35 00
" 17.—New bottom and jambs to dandy	14 00
March 10.—New doors and repairing jambs and end of dandy	12 50
	$74 00

During this period 554 tons 1,496 lbs. of iron were produced, so that the repairs would amount to about 13¼ cents per ton. In this double furnace, as will be seen by the items of cost, the neck of the furnace has been enlarged so as to make room for a "dandy," or chamber next the throat of the furnace for preheating the iron.

There is not included in the above the occasional cost of renewing the cast-iron part of the retort, which generally lasts from 40 to 42 weeks, after which the lower section of it must be renewed. This is done by tearing down one side of the brick casing, or retort-chamber; the retort is then taken out sidewise. This change is made in 1½ days. The retort sometimes cracks before it is quite worn out; in this case the cracked side is covered with bricks on edge, and this precaution is found sufficient to prevent any further damage. The air-apparatus—that is to say, the air-vessel G and the circuit pipes—lasts indefinitely. The brick casing around the retort generally lasts as long as two cast-iron retorts.

The repairs are much less frequent on heating-furnaces; they have sometimes run 26 weeks, welding large, dry piles, without any repairs except a new fire-bridge wall.

Raising Steam *vs.* Regeneration.—Raising steam by the waste gases of heating and puddling furnaces has been deemed an important economy, especially in iron-mills where the furnace temperatures were high. But even in these cases, a comparison of the fuel burned economically in producers for regenerative furnaces, and under well-arranged boilers, with that burned necessarily wastefully in common furnaces with boilers over them, has shown a considerable economy in favor of applying waste heat to regeneration. Although such a comparison has not been directly made in the case of the Price furnace, a similar result may be predicated on the numerous trials with the Siemens furnace.

The use of boilers over *steel*-heating furnaces has not proved a success. In several prominent works, such boilers have been removed; they did not make steam enough to pay for attendance.

But the whole matter of the comparative saving of fuel by

regeneration and by steam-raising is of minor importance when compared with that of saving in the oxidation of the costly materials which are treated in the furnace. A saving of two per cent. in the oxidation of fine merchant iron in its average number of re-heats, could hardly be less than $1 50 per ton, and this would pay for a new set of furnaces in less than a year.

It has, however, been proposed to raise steam by the waste heat of the Price furnace; for, well as it has utilized this heat, as proved by the foregoing results, there is still some left. Experiments made by the Woolwich authorities, extending over a period of two days, showed that the temperature in a reheating-furnace stack varied between 1,100 and 1,400 degrees, the average being 1,260 degrees F. That in the flues of the puddling-furnaces ran higher, but the heat has never been accurately measured; it is thought it would range between 1,600 and 1,800 degrees; but it is questionable whether heat enough would be regularly obtained for the purpose of raising steam economically. The heat in the puddling-furnace is visibly much higher than in the heating-furnace; for at five feet above the ground, the heating-furnace stack remains a dull red, while at the same height the puddling-furnace stack is often cherry-red. Loose bricks are left purposely in each stack, so as to observe the heat; the furnace-man is thus enabled to judge of the temperature in his furnace, and can control it accordingly by the blast or by the amount of coal on the grate, as the case may be.

Cost.—The furnace shown in the engraving (of which I have detail drawings) was designed to heat five or six 4-rail steel ingots or a larger number of double-rail blooms, but it is adapted to iron piles. It is 12 feet long on the bed.

The important elements of cost are the following:

Materials.	*Quantities.*
Rubble	57 feet.
Common fire-brick, laid	12½ M.
Best " "	7 "
Plate iron } not including hopper	5,000 lbs.
Castings } not including hopper	41,000 "
Bolts	1,350 "
Bar-iron	2,000 "

As the prices of these materials vary in different localities, I will not attempt to give an exact estimate. In round numbers, this furnace would cost $3,000, not including the stack. Of this sum the hopper would cost about $200.

The cost of altering an old furnace to the Price system would depend upon the situation of the furnace with reference to the stack, and upon other circumstances. Should the stack stand at the throat end, an underground flue could be readily brought to it from the retort-chamber; should the stack be at the retort end, the connection would be short and simple. An old furnace would require a new fire-box and a retort-chamber and its appurtenances. The plates of the old fire-box might be utilized. Probably altering an old furnace would cost $2,000.

Mr. Ronald, before quoted, says that a double retort puddling-furnace, with Witham's rabble, would cost, in England, only about $2,500.

Conclusion.—I. While there can hardly be such perfect combustion and such control of the flame in this furnace as in a furnace where the fuel is exclusively gas, it is nevertheless obvious that the Price furnace has the economical advantage of utilizing the original heat of the gases—there is no heat wasted in producers and cooling tubes.

II. The Price system will recommend itself very strongly for existing works, on account of its cheapness and its ready application to existing furnaces, or at least to existing mills, especially where it is impracticable, on account of water, to put regenerators ten feet below the mill floor.

III. As the gases are uniformly distilled in the retort, their combustion, as they meet the air coming through the grate, must be approximately complete.

IV. This constant flow of gases intercepts the air that comes through the grate and applies it to the combustion of fuel rather than to the combustion of iron. In the ordinary fire-box, a caking coal, especially, must make a fire of irregular thickness and often full of holes, so that much air passes over the bridge to oxidize the metal.

V. Red-hot coke or coal, distributed regularly over the

grate, without the admission of air through the fire-door, tends to the maintenance of an even heat in the furnace; but firing cold fuel, which is also often wet, suddenly cools the furnace, fills the heating-chamber with smoke and watery vapor, and checks not only combustion but metallurgical operations.

VI. The further utilization of waste heat and improvement of combustion by means of preheating the blast, has been tried in various ways with success. Price's system seems to be thorough, and the apparatus is durable.

Finally, it may be said that this furnace is now completely beyond the experimental stage, and that its construction and practice are settled and well defined.